Principled Technologies®

Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

Executive summary

Intel Corporation (Intel) commissioned Principled Technologies (PT) to compare the performance of five computing models on test beds with varying numbers of active clients, each running the same typical office application tasks. We measured the response time users would experience on each system while performing common office functions with leading Microsoft Office and Adobe Acrobat applications. We set up test beds to test the following computing models[1]:

- **Terminal/Presentation server**—thin clients administered using Citrix Presentation Server 4.5
- **Typically managed rich desktop**—rich clients
- **Well-managed OS streaming desktop/vPro**—rich clients with Intel vPro technology with the OS streamed from the server and Ardence Evaluation Client 4.1, administered using Ardence Evaluation Server 4.1 OS
- **Blade PC desktop**—thin clients connected to Blade PCs
- **Well-managed application streaming desktop/vPro**—rich clients with Intel vPro technology running AppStream Technology Windows Edition 5.2.1 client software with applications streamed using AppStream Technology Windows Edition 5.2.1 server software

All rich clients were hand-built rich clients (Intel Desktop Board DQ965GF, 2.13 GHz Intel Core 2 Duo E6400, 1GB DDR2 SRAM running Windows XP Professional version 2002 with Service Pack 2). All thin clients were Wyse Winterm V50 thin clients. For the Blade PC desktop model we used HP BladeSystem bc2000 Blade PCs (AMD Athlon 64 2100+ 1.20GHz, 1GB DDR2 RAM running Windows XP Professional version 2002 with Service Pack 2). We collected performance data and server CPU utilization data while running compute-intensive tasks on each computing model. For models that require access infrastructure servers, we used the data to estimate the number of clients that a server can realistically support. Rich desktop models showed the fastest performance; computing models that use access infrastructure servers for compute tasks were slower at higher client counts due to server congestion; the Blade PC platform was relatively slow at all client counts. We used the performance data and estimates of the frequency of the compute-intensive tasks that would cause model slowness to estimate minutes of lost productivity per user per day due to platform slowness. Figure 1 shows these estimates.

Model	Number of clients per server	Minutes of lost productivity per user per day due to model slowness
Terminal/Presentation server	57.0	3.25
Typically managed rich desktop	n/a	0.0
Well-managed OS streaming desktop/vPro	153.0	0.75
Blade PC desktop	n/a	7.70
Well-managed Application streaming desktop/vPro	399.0	0.0

Figure 1: Estimated number of clients per access infrastructure server and minutes of lost productivity per user per day due to platform slowness for various computing models.

---

[1] These tests were part of a larger computing model comparison that considered the costs and benefits of typically managed compared to well-managed models and the costs and benefits of Intel vPro technology. We refer to these features in model names for consistency with other related reports even though they do not affect the platform performance and sizing that is the focus of this document.

In this context, an access infrastructure server is one that does the work that would be done on a rich client in a traditional environment. Server congestion occurs when the combined needs of the many clients accessing one server exceed the available server resources. Server congestion is not applicable to the two rich desktop or the Blade PC desktop computing models which have a one-to-one ratio of users to devices.

Each of our test beds included a file server and 10 client systems. We used a pair of identical file servers to allow us to test two computing models at a time. Our hand-built file server included a 3.4 GHz Intel Xeon processor, 2GB DDR2 SRAM, an HP 382146-405 motherboard, and a Western Digital WD740ADFD-00NLR1 disk and ran Windows Server 2003 R2 Enterprise with Service Pack 2. We used a 100Mbps network infrastructure for the clients, and a 1Gbps network infrastructure for the servers to reflect typical scenarios in enterprises today. We also set up access infrastructure servers for computing models that require them. Our hand-built access infrastructure server included two 3GHz Intel Xeon 5160 dual-core processors, 16GB DDR2 SRAM, a Supermicro X7DBE+ motherboard, and four 73GB Seagate Cheetah ST373455SS disks and ran Windows Server 2003 R2 Enterprise with Service Pack 2 and other software required by each computing model. Appendix A provides high-level configuration information on all of the systems used in our test; and Appendix B provides greater detail.

To compare computing model performance, we ran three different applications scenarios on each computing model:

- **Acrobat compress.** This single-task scenario tested how quickly the test system was able to open Acrobat and compress a 4.01MB PDF file (located on the file server) from within the Acrobat application.
- **Excel subtotals.** This single-task scenario tested how quickly Excel could perform the subtotal function on a 1.79MB Excel worksheet (located on the file server).
- **Explorer compress and PPT change view.** This multitasking scenario tested how long it took to compress a 265MB folder (located on the file server for the thin clients; local for the rich clients) while changing views within a 30.4MB Microsoft PowerPoint presentation (located on the file server).

We evaluated the performance of each of the application scenarios with automated test scripts, which we developed with IBM's Visual Test 6.5. We hand-timed the scenarios to confirm the automated results. In this document, we focus on the results of the automated scripts because those results are generally more repeatable than hand timings, especially in tests involving multiple clients running simultaneously.

We installed the Microsoft Office 2003 and Adobe Acrobat 8.0 Professional applications so that they would be available to all the clients. The test scripts run tasks in these applications. Because the thin clients do not have disks, all their applications and data files reside on the servers appropriate to the configuration in use. We installed the PC applications on each PC, but to reflect the nature of today's office environments, we stored the data files on the file server except for the Explorer compress and PowerPoint change view test where storing a file locally made more sense in the usage model.

We ran the three test scripts on each test bed with four client configurations: first with a single client running the script, then with 2, 5, and 10 clients simultaneously running the script. This approach allowed us to gauge the response-time effects on end users of adding clients to each test bed.

The rest of this report describes the test environment, tests, results, and analysis. The **Compute model enterprise view** section describes the general test bed configuration. The **Test results** section reports performance and server CPU utilization during the three tests. The **Results analysis** section shows the calculations and estimates for the number of clients per access infrastructure server and for lost user productivity due to server congestion on the access infrastructure servers. The **Test bed setup** section gives instructions for setting up the test beds. The **Running the tests** section gives instructions for running the automated test scripts. The final section, **Application scenarios: Descriptions and instructions for running manually**, details the steps we followed when we hand-timed the scenarios to confirm the automated results. The automated scripts mimic these steps. Appendix A includes test bed diagrams, and Appendix B gives detailed descriptions of the clients and servers.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations
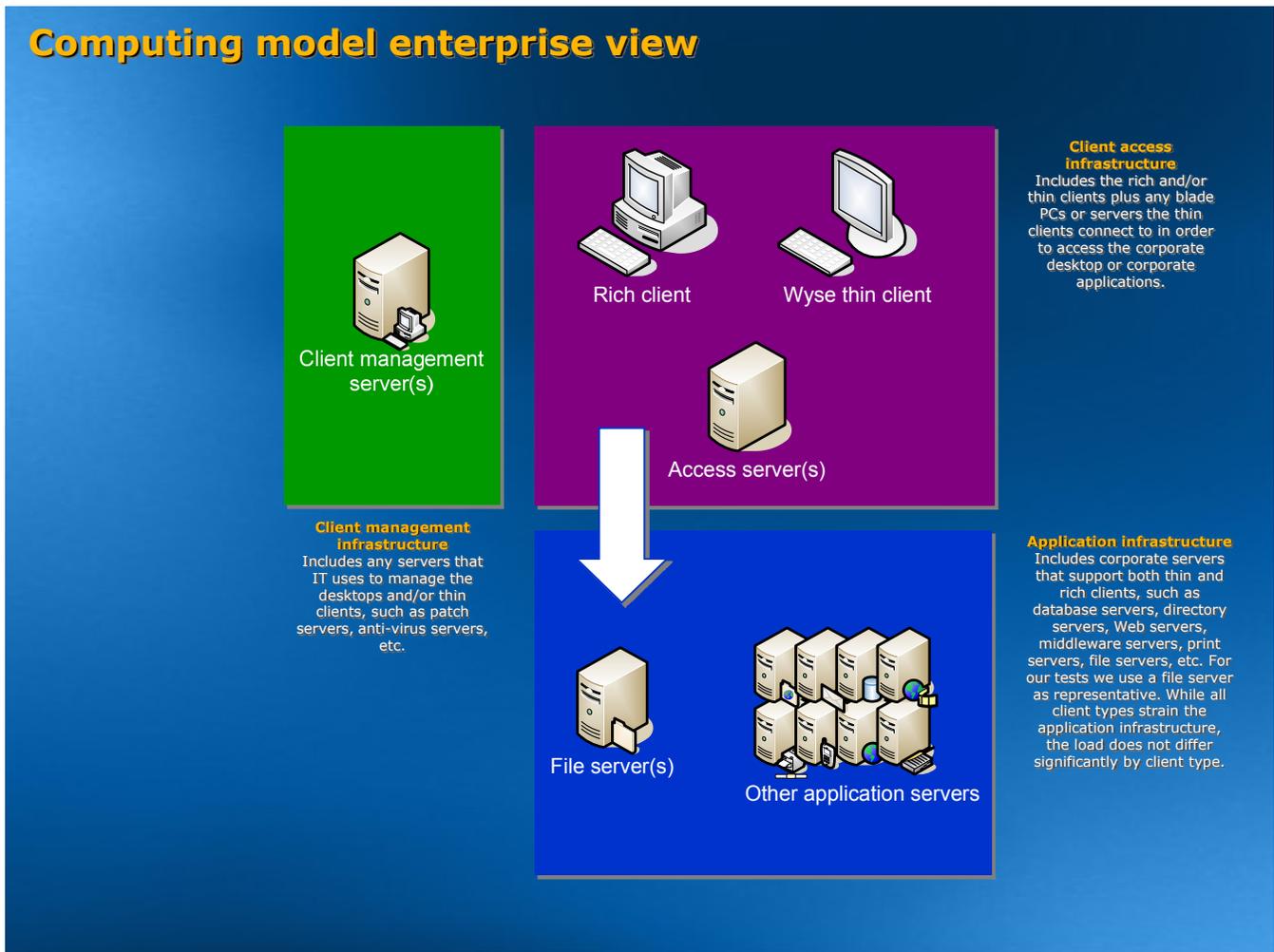
2

Computing model enterprise view

Figure 2: A model of an enterprise infrastructure including client management infrastructure, client access infrastructure, and application infrastructure.

Each test bed represented a subset of an enterprise computing system. We assumed the enterprise compute model included three infrastructures:

- Access infrastructure made up of clients. Depending on the computing model, these would include thin clients, rich clients, and blade PCs. The access infrastructure also includes, for some computing models, access infrastructure servers to host the desktop and any running applications.
- Application infrastructure that includes one or more file servers as well as application servers that provide email, database, network services (DNS, Active Directory), and Web services.
- Client management infrastructure that automates client management software.

Figure 2 defines the three infrastructures within a general compute model enterprise view and Appendix A lists the test bed components and illustrates the computing models for each of the five computing models. Each test bed included client systems and a file server to store the test files. The thin clients do not have disks, so they had an access infrastructure server to host the desktop and any running applications. Because client management would not affect the access infrastructure server performance central to this study, we did not include client management servers in our test bed other than the application streaming server. Likewise, we omit from our test bed the application servers other than a file server that enterprise infrastructures typically include.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

3

The analysis we document in this paper had two goals: (1) to estimate the number of clients that an access infrastructure server can realistically support on computing models that use them and (2) to quantify the average lost user productivity per day due to platform slowness. We looked at two causes of slowness: congestion on the access infrastructure servers and, in the case of Blade PC desktop computing model, the slowness of the blades. The next section describes the results.

Test results

For each test script on each test bed, we first performed the following script setup steps:

- rebooted (in the appropriate order; discussed more below) the systems in the test bed
- created a desktop shortcut for the test script
- created a desktop shortcut for the setup script that prepares the data files for testing
- created a desktop shortcut for the script that cleans up data files between runs of the script
- ran the setup script
- rebooted the systems in the test bed

After we finished this setup process for each script, we ran that script on that test bed five times for each with a single client, then with 2, 5, and 10 clients running simultaneously. If any test or script failed, we discarded that test's results and ran the test again. We ran the script that cleans up data files between runs. We rebooted the test bed systems, the file server, and the access infrastructure server (if the test bed included one) between each run of each test script.

Figure 3 displays the sum of the execution times for one run of each of the three tests at each of the four client loads for each of the computing models. We used these times in calculations of the lost user productivity per day and the number of clients an access infrastructure server can support. The Results analysis section describes those calculations.

Number of clients	1	2	5	10
Terminal/Presentation server	30.6	34.0	58.3	116.3
Typically managed rich desktop	46.6	48.7	54.9	67.5
Well-managed OS streaming desktop/vPro	47.5	50.7	59.4	78.7
Blade PC desktop	111.3	110.5	112.3	113.6
Well-managed application streaming desktop/vPro	48.6	50.4	53.5	64.8

Figure 3: Sum of script execution times for all tests (all times in seconds, lower is better).

Results analysis

Our aim was to estimate for each computing model the lost productivity per user per day and the number of clients an access infrastructure server can realistically support. We relied on the test results in the section above in making these estimates.

The workers in the example enterprise are knowledge workers. Knowledge workers perform a mixture of high-, medium-, and low-demand tasks, primarily medium-demand tasks. Their demand is higher than light or transactional users who use few applications to carry out repetitive, low-demand tasks, and lower than power or heavy users who typically run high-demand applications such as 3-D design applications and complex financial applications. Knowledge workers typically use a variety of applications, in the case of this enterprise a total of 120 applications among all the users. They also frequently leave multiple applications open simultaneously and

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

4

frequently work in medium to large files. Typical applications include Microsoft Office and complex line-of-business applications such as accounting and resource planning applications.

Our three tests include processor-intensive operations in Microsoft Office and Adobe Acrobat, applications that are typical of those that knowledge workers use day to day. The results for our example enterprise should be relevant to other enterprises selecting a computing model for a group of predominantly knowledge workers. An enterprise with all light or transactional users would see less lost productivity and an organization with more heavy or power users would likely need more servers and experience additional lost productivity.

Shared server penalty and lost productivity per user per day

When multiple users are simultaneously executing server-intensive tasks, some or all users may have to wait because the server is unable to process all their work quickly enough. To quantify the amount of time users lose to waiting during these instances, we followed this process:

1. Sum the total number of seconds it took each client to complete our three tests on the computing model in question when 10 users were running at once. (See the 10-client column in Figure 3 or the total times column in Figure 4.)
2. Subtract the sum of the times the rich clients required to execute the same tasks.

The result is the shared server penalty in productivity. Figure 4 shows the results of this calculation.

Script name	Excel subtotals	Acrobat compress	Explorer compress and PowerPoint change view	Total times	Shared server penalty
Terminal/Presentation server	18.4	42.1	55.8	116.3	48.8
Typically managed rich desktop	10.0	28.4	29.1	67.5	0.0
Well-managed OS streaming desktop/vPro	10.1	30.3	38.3	78.7	11.2
Blade PC desktop	25.9	57.0	30.8	113.6	46.1
Well-managed application streaming desktop/vPro	10.1	26.8	27.9	64.8	-2.7

Figure 4: Script execution times for 10 users and shared server penalty (all times in seconds; lower is better).

We estimated that the typical eight-hour workday contains at least the following four periods of peak usage when more than 10 users per server are simultaneously executing server-intensive tasks and would therefore encounter delays equal to or greater than those we report with 10 clients:
- at the beginning of the workday
- before lunch
- after lunch
- at the end of the workday

To calculate a conservative estimate for total daily penalty per user per eight-hour workday, we multiplied the shared server penalty by four.

In the case of the Blade PC desktop, however, the script execution times were significantly slower than rich clients at even one concurrent user. Therefore, we estimate that 10 times during the eight-hour workday, a typical user is attempting compute-intensive tasks. We then multiply the shared server penalty for Blade PC desktop by 10 to get the total daily penalty for an eight-hour workday.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

5

Figure 5 shows the results of these calculations. Note: For Well-managed application streaming desktop/vPro, we rounded the shared server minutes lost per day results to zero.

Script name	Shared server penalty (seconds)	Multiplier	Lost productivity per user per day (minutes)
Terminal/Presentation server	48.8	4.0	3.3
Typically managed rich desktop	0.0	4.0	0.0
Well-managed OS streaming desktop/vPro	11.2	4.0	0.7
Blade PC desktop	46.1	10.0	7.7
Well-managed Application streaming desktop/vPro	-2.7	4.0	0.0

Figure 5: Lost user productivity lost per day (in minutes).

Number of clients an access infrastructure server can support

To calculate the number of clients an access infrastructure server can support in comparison to rich client performance, we used the following formula:

$$\frac{\text{number of clients}}{\text{percentage CPU utilization}} \times \frac{\text{number of actual clients each test client represents}}{} \times \frac{\text{rich client time}}{\text{shared platform time}}$$

raw client count   *client factor*

estimated number of real clients   *shared platform speed normalized to rich client*

The italicized labels explain what each section of the formula represents:

Raw client count. To determine raw client count, we divided the number of clients simultaneously executing server-intensive tasks by the average percentage of CPU utilization during the test. For our analysis, we used the 10-client case, so the number of clients was always 10.

Figure 6 shows average access infrastructure server CPU utilization for each computing model during a 10-client run of each of the three tests:

Test	Excel subtotals	Acrobat compress	Explorer compress and PowerPoint change view
Terminal/Presentation server	96.44%	99.87%	89.50%
Typically managed rich desktop	n/a	n/a	n/a
Well-managed OS streaming desktop/vPro	0.66%	0.98%	6.13%
Blade PC desktop	n/a	n/a	n/a
Well-managed application streaming desktop/vPro	24.84%	0.50%	16.60%

Figure 6: Average server CPU during median run for 10-client test. Lower is better. Typically managed rich desktop and Blade PC desktop platforms do not use access infrastructure servers so their results are not applicable.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

6

Client factor. All of our test clients simultaneously performed server-intensive tasks. To account for the fact that only a percentage of any real-life group of clients would be executing server-intensive tasks at any given time, we assigned a client factor: the number of actual users each test client in our tests represented. Our default client factor was 10, reflecting an industry-standard range of 8 to 10.

Estimated number of real clients. The product of the raw client count and the client factor was the estimated number of real clients the computing model could support if all computing models executed the tasks in the same amount of time. Because this was not the case, we used one additional factor to account for the variation in speed.

Platform speed normalized to rich client. For the last factor, we divided the task completion time on the rich client platform by the task completion time on the shared server platform. Poorer performance on the shared server platform than on the rich client platform indicated that the server had too many clients, because we treated the rich client platform as the baseline for performance. Put differently, normalizing to the rich client's performance estimated the number of clients the server could handle while providing the rich client's level of performance.

The server for the OS streaming platform was not constrained by the processor as it was on all of the other alternative computing models. To account for this, we used three special tests we describe below. We then used the minimum calculated number from these formulas to estimate the number of clients per OS streaming server.

1. **Calculating clients per server during a disk-intensive task.** In this case, the task was compressing a large file located on the OS streamed disk. We used the same formula as above during this disk-intensive task.

$$\frac{\text{number of clients}}{\text{percentage CPU utilization}} \quad x \quad \frac{\text{number of clients}}{\substack{\text{each client} \\ \text{represents}}} \quad x \quad \frac{\text{rich client time}}{\text{shared platform time}}$$

2. **Measuring network utilization during a 10-client boot storm.**

$$\frac{\text{number of clients}}{\substack{\text{percentage network} \\ \text{utilization}}} \quad x \quad \frac{\substack{\text{number of real} \\ \text{clients}}}{\substack{\text{each test client} \\ \text{represents}}} \quad x \quad \frac{\text{OS streaming single-client boot time}}{\text{OS streaming 10-client boot time}}$$

raw client count   *client factor*

                                                OS streaming 10-client boot time normalized to the OS streaming

estimated number of real clients   *single-client boot time*

Raw client count. To determine raw client count, we divided the number of clients simultaneously executing network-intensive tasks by the peak percentage network utilization during the boot cycle. For our analysis, we used the 10-client case, so the number of clients was always 10.

Client factor. All of our test clients simultaneously performed network-intensive tasks. To account for the fact that only a percentage of any real-life group of clients would be executing these tasks at any given time, we assigned a client factor: the number of actual clients each client in our tests represented. Our default client factor was 10, reflecting an industry-standard range of 8 to 10.

Estimated number of real clients. The product of the raw client count and the client factor was the estimated number of real clients the computing model could support if all computing models executed the tasks in the same amount of time. Because this was not the case, we used one additional factor to account for the variation in speed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

7

OS streaming. 10-client boot time normalized to the OS streaming single-client boot time. For the last factor, we divided the boot completion time of a single client by the 10-client boot completion time. Normalizing to the single client performance estimated the number of clients the server could handle while providing the single client's level of performance.

3. **Measuring network performance during a typical test.** We used our Adobe Acrobat test and a formula very similar to that in case 2 above.

$$\underbrace{\overbrace{\frac{\text{number of clients}}{\text{percentage network utilization}}}^{\textit{raw client count}} \times \overbrace{\begin{array}{c}\text{number of real}\\\text{clients}\\\text{each test client}\\\text{represents}\end{array}}^{\textit{client factor}}}_{\textit{estimated number of real clients}} \times \underbrace{\frac{\text{OS streaming single-client test duration}}{\text{OS streaming 10-client test duration}}}_{\begin{array}{c}\textit{OS streaming 10-client test time}\\\textit{normalized to the OS streaming single-}\\\textit{client test time}\end{array}}$$

Raw client count. To determine raw client count, we divided the number of clients simultaneously executing network-intensive tasks by the peak percentage network utilization during the test. For our analysis, we used the 10-client case, so the number of clients was always 10.

Client factor. All of our test clients simultaneously performed network-intensive tasks. To account for the fact that only a percentage of any real-life group of clients would be executing these tasks at any given time, we assigned a client factor: the number of real clients each client in our tests represented. Our default client factor was 10, reflecting an industry-standard range of 8 to 10.

Estimated number of real clients. The product of the raw client count and the client factor was the estimated number of real clients the computing model could support if all computing models executed the tasks in the same amount of time. Because this was not the case, we used one additional factor to account for the variation in speed.

OS streaming. 10-client test time normalized to the OS streaming single-client test time. For the last factor, we divided the test completion time of a single client by the 10-client test completion time. Normalizing to the single client performance estimated the number of clients the server could handle while providing the single client's level of performance.

Figure 7 shows the results of these calculations.

Script name	Excel subtotals	Acrobat compress	Explorer compress and PowerPoint change view	Well-managed OS streaming desktop/vPro special test cases (minimum)	Number of clients per server (rounded to nearest whole number)
Terminal/Presentation server	56.57	67.51	58.27	n/a	57
Typically managed rich desktop	n/a	n/a	n/a	n/a	n/a
Well-managed OS streaming desktop/vPro	15036.25	9548.80	1239.27	153.49	153
Blade PC desktop	n/a	n/a	n/a	n/a	n/a
Well-managed Application streaming desktop/vPro	399.00	21153.40	628.27	n/a	399

Figure 7: Estimated number of users per server, determined by the worst-case number of users per server for the three or four tests. These estimates did not apply to Typically managed rich desktop or Blade PC desktop platforms, none of which require access infrastructure servers.

Test bed setup

We performed the initial setup of the shared file server the same way on all the test beds. The first subsection below outlines that process. The thin clients do not have disks, so they had two servers: a file server to hold the test data and another server to hold the configuration applications. Because we were testing different Well-managed application streaming desktop/vPro configurations for the rich clients, they too had a file server and an access server. Some of the rich client configurations required local installation for the applications the test scripts use. The subsequent subsections discuss each test bed and the steps we took to set it up. Each of those discussions includes three sections:

- Test bed-specific setup instructions for setting up the access infrastructure server
- Instructions for setting up the clients
- Additional instructions for client setup

Some setup steps were the same for all the test beds, while others were specific to each network. We note the differences. Appendix A describes and diagrams each test bed.

Setting up the file servers for the test beds

We followed this process to initially prepare each file server.

1. Install a copy of Microsoft Windows 2003 Server Enterprise Edition, R2.
2. Apply the following updates from the Microsoft Windows Update site:
   - Windows Server 2003 Service Pack 2
   - Windows Server 2003 update (KB927891)
   - Windows Server 2003 Security Update (KB929123)
   - Windows Server 2003 Security Update (KB930178)
   - Windows Server 2003 Security Update (KB931784)
   - Windows Server 2003 Update (KB932168)
   - Windows Server 2003 Security Update (KB932168)
   - Windows Server 2003 Security Update (KB933566)
   - Windows Server 2003 Security Update (KB935839)
   - Windows Server 2003 Security Update (KB935840)
   - Windows Server 2003 Security Update (KB924667-v2)
   - Windows Server 2003 Security Update (KB925902)
3. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Security Center.
   c. Click Change the way Security Center Alerts me on the left.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

9

      d.   Uncheck Firewall, Automatic Updates, and Virus Protection.
4. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
      a.   Open the Control Panel.
      b.   Choose Automatic Updates.
      c.   Select Turn off Automatic Updates.
5. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
      a.   Open the Control Panel.
      b.   Choose System.
      c.   Choose the System Restore tab.
      d.   Select Turn off System Restore on all drives.
6. Set up the script folders for each test system (PC or thin client):
      a.   Create a folder named User Files.
      b.   Within that folder, create 10 folders, named User1 through User10. These folders will hold the individual script directories.
7. Copy the three script folders into each of these directories. You will end up with 10 copies of the scripts, one for each user. These folders contain all of the files the scripts need to execute. Each of the three script folders' names identifies the test script. Each of those folders contains a folder named SC1. Each SC1 folders contains the same three subfolders:
      a.   Content: all the test files the script uses
      b.   Results: initially empty but will contain the results file the script creates
      c.   Scripts: the script's source and executable files.
8. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
9. Using Symantec's Ghost utility, make an image of the hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Setting up the Terminal/Presentation server test bed

We set up the Terminal/Presentation server test bed by arranging the 10 Wyse Winterm V50 thin clients in a network with a 100Mbps switch. We connected the file server and access infrastructure server to each other through a 1Gbps switch. We then connected the two switches to each other using a 1Gbps uplink port.
1. Install a copy of Microsoft Windows 2003 Server Enterprise Edition, R2.
2. Apply the following updates from the Microsoft Windows Update site:
   - Windows Server 2003 Service Pack 2
   - Windows Server 2003 update (KB927891)
   - Windows Server 2003 Security Update (KB929123)
   - Windows Server 2003 Security Update (KB930178)
   - Windows Server 2003 Security Update (KB931784)
   - Windows Server 2003 Update (KB932168)
   - Windows Server 2003 Security Update (KB932168)
   - Windows Server 2003 Security Update (KB933566)
   - Windows Server 2003 Security Update (KB935839)
   - Windows Server 2003 Security Update (KB935840)
   - Windows Server 2003 Security Update (KB924667-v2)
   - Windows Server 2003 Security Update (KB925902)
3. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
      a.   Open the Control Panel.
      b.   Choose Security Center.
      c.   Click Change the way Security Center Alerts me on the left.
      d.   Uncheck Firewall, Automatic Updates, and Virus Protection.
4. Install Microsoft Office 2003
5. Apply all Office 2003 updates (as of July 10, 2007) from the Microsoft Office Update Web site.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

10

6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Automatic Updates.
   c. Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose System.
   c. Choose the System Restore tab.
   d. Select Turn off System Restore on all drives.
8. Create 10 users (USER1 through USER10). Give each user remote desktop privileges and the password "password".
9. Install Citrix Presentation Server using all defaults.
10. Set up USER1 through USER10 so each account has Citrix user and remote desktop permissions.
11. Configure the Visual Test Runtime application so that it will work with all the test scripts:
    a. Copy the following five Visual Test dll files into /WINDOWS/SYSTEM32:
       - IEHelper.dll
       - Vtaa.dll
       - VTest60.dll

       - Vtres.dll
       - WebDrive.dll
    b. Open a command prompt.
    c. Type cd \WINDOWS\SYSTEM32, and press Enter.
    d. For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
       - IEHelper.dll
       - Vtaa.dll
       - WebDrive.dll
12. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
13. Using Symantec's Ghost utility, make an image of the hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)
14. Install Adobe Acrobat 8.0 Professional.

Setting up the thin clients
1. Boot the file server.
2. Boot the Citrix server
3. Boot the thin client.
4. Change the IP address of the thin client to 192.168.1.5[X], where X is the number of the client.
   a. Click Start → Control Panel → Select Network Connections.
   b. Select Local Area Connection.
   c. In the Local Area Connection Status dialog, select Properties.
   d. In the Local Area Connection Properties dialog, select Properties.
   e. Select the Use the following IP address radio button.
   f. Enter the IP Address.
   g. Select OK on the top two open dialog boxes.
   h. Select Close to close the third dialog box.
5. Configure each thin client to have a display resolution of 1,280 x 1,024 and 24-bit color depth.
6. Create a remote desktop connection with the Citrix server.
   a. Click Start → Connection Manager.
   b. In the Connection manager window, click Add.
   c. In the first window, select ICA and click Next.
   d. Under the Network tab, enter the following:
      i. In the Description box: Citrix

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

11

ii. In the Server box: 192.168.1.250
   e. Under the Window tab, set the Window Colors to 16 Million and the Window Size to Full screen.
   f. Under the Login tab, enter the following:
      i. In the User Name box: user[X] where X is as above
      ii. For the password: password
      iii. For the Domain: server
7. Double-click the Citrix icon to connect to the Citrix server
8. Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
   a. Right-click My Computer.
   b. Select Map Network Drive.
   c. Select Q: from the Drive drop-down menu.
   d. Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
   e. Click Finish.
9. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
10. Click Start→Shut Down.
11. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
12. Type an explanatory comment in the comment box.
13. Press enter.
14. You may see a warning window that says shutting down will close the remote connections and asks if you want to end them. Click Yes, and the file server will restart.

Setting up the Typically managed rich desktop test bed

We set up the Typically managed rich desktop and test bed by arranging the 10 desktop systems in a network with a 100Mbps switch. We then connected this switch through a 1Gbps uplink to the file server.

Setting up the access infrastructure server in the Typically managed rich desktop test bed

The Typically managed rich desktop test bed does not require any servers beyond the file server.

Setting up the PC clients

Repeat these steps on each of the 10 PC clients.
1. Install Windows XP Professional on each of the clients.
2. Apply all XP updates (as of July 10, 2007) from the Microsoft Windows Update Web site, including Windows XP SP2.
3. Install Microsoft Office 2003.
4. Apply all Office 2003 updates (as of July 10, 2007) from the Microsoft Office Update Web site.
5. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Security Center.
   c. Click Change the way Security Center Alerts me on the left.
   d. Uncheck Firewall, Automatic Updates, and Virus Protection.
6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Automatic Updates.
   c. Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose System.
   c. Choose the System Restore tab.
   d. Select Turn off System Restore on all drives.
8. Change the PC's IP address to 192.168.1.5[X], where X is the client number of the PC. (We numbered the PCs 1 through 10 with the last address being 192.168.1.60.)
   a. Click Start → Control Panel → Select Network Connections.
   b. Select Local Area Connection.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

12

    c.   In the Local Area Connection Status dialog, select Properties.
    d.   In the Local Area Connection Properties dialog, select Properties.
    e.   Select the Use the following IP address radio button.
    f.   Enter the IP Address.
    g.   Select OK on the top two open dialog boxes.
    h.   Select Close to close the third dialog box.
9.   Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
    a.   Right-click My Computer.
    b.   Select Map Network Drive.
    c.   Select Q: from the Drive drop-down menu.
    d.   Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
    e.   Click Finish.
10. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
11. Configure the Visual Test Runtime application so that it will work with all the test scripts:
    a.   Copy the following five Visual Test dll files into \WINDOWS\SYSTEM32:
- IEHelper.dll
- Vtaa.dll
- VTest60.dll
- Vtres.dll
- WebDrive.dll

    b.   Open a command prompt.
    c.   Type cd \WINDOWS\SYSTEM32, and press Enter.
    d.   For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
- IEHelper.dll
- Vtaa.dll
- WebDrive.dll

12. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk of each PC.
13. Using Symantec's Ghost utility, make an image of each PC's hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)
14. Install Adobe Acrobat 8.0 Professional.

Additional client setup
The PC test bed does not require any additional client setup.

Setting up the Well-managed OS streaming desktop/vPro test bed
We set up the Well-managed OS streaming desktop/vPro test bed by arranging the 10 desktop systems in a network with a 100Mbps switch. We connected the file server and access infrastructure server to each other through a 1Gbps switch. We then connected the two switches to each other using a 1Gbps uplink port.

Setting up the access infrastructure server in the Well-managed OS streaming desktop/vPro test bed
1.   Install a copy of Microsoft Windows 2003 Server Enterprise Edition, R2.
2.   Apply the following updates from the Microsoft Windows Update site:
- Windows Server 2003 Service Pack 2
- Windows Server 2003 update (KB927891)
- Windows Server 2003 Security Update (KB929123)
- Windows Server 2003 Security Update (KB930178)
- Windows Server 2003 Security Update (KB931784)
- Windows Server 2003 Update (KB932168)
- Windows Server 2003 Security Update (KB932168)
- Windows Server 2003 Security Update (KB933566)
- Windows Server 2003 Security Update (KB935839)
- Windows Server 2003 Security Update (KB935840)
- Windows Server 2003 Security Update (KB924667-v2)

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

13

- Windows Server 2003 Security Update (KB925902)
3. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Security Center.
   c. Click Change the way Security Center Alerts me on the left.
   d. Uncheck Firewall, Automatic Updates, and Virus Protection.
4. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Automatic Updates.
   c. Select Turn off Automatic Updates.
5. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose System.
   c. Choose the System Restore tab.
   d. Select Turn off System Restore on all drives.
6. Start the Windows DHCP service for the server.
7. Install Ardence server, making sure that every option is set so that the local server handles it.
8. Start Ardence Administrator.
9. Determine which computer will act as the prime client, and manually add its MAC address to Ardence Administrator's client list.
10. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
11. Using Symantec's Ghost utility, make an image of the hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Setting up the Well-managed OS streaming desktop/vPro clients
Repeat these steps on each of the 10 Ardence clients.
1. Change the system's boot order so that network boot will be the first method listed.
   a. Turn on the system and access the BIOS using the appropriate key.
   b. Using the directional arrows on the keyboard highlight the boot order option.
   c. Following the directions on the screen place "network boot" in the number one position.
   d. Save your changes and exit the BIOS.

Additional client setup
The following setup is to be used only once at the beginning of the network setup. Only one client is involved so do not repeat these steps on the other systems.
1. Install Windows XP Professional.
2. Apply all XP critical updates (as of July 10, 2007) from the Microsoft Windows Update Web site, including Windows XP SP2. Do not install any of the optional updates.
3. Install Microsoft Office 2003.
4. Apply all Office 2003 updates (as of July 10, 2007) from the Microsoft Office Update Web site.
5. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Security Center.
   c. Click Change the way Security Center Alerts me on the left.
   d. Uncheck Firewall, Automatic Updates, and Virus Protection.
6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Automatic Updates.
   c. Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

14

     a. Open the Control Panel.
     b. Choose System.
     c. Choose the System Restore tab.
     d. Select Turn off System Restore on all drives.
8. Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
     a. Right-click My Computer.
     b. Select Map Network Drive.
     c. Select Q: from the Drive drop-down menu.
     d. Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
     e. Click Finish.
9. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
10. Configure the Visual Test Runtime application so that it will work with all the test scripts:
     a. Copy the following five Visual Test dll files into \WINDOWS\SYSTEM32:
        • IEHelper.dll
        • Vtaa.dll
        • VTest60.dll
        • Vtres.dll
        • WebDrive.dll
     b. Open a command prompt.
     c. Type cd \WINDOWS\SYSTEM32, and press Enter.
     d. For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
        • IEHelper.dll
        • Vtaa.dll
        • WebDrive.dll
11. Install Adobe Acrobat 8.0 Professional.
12. Install Ardence Client on the system.
13. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk of each PC.
14. Restart the client, making sure that it restarts locally.
     a. In Ardence Server Administrator set the client that contains the Windows/Office/Acrobat applications to force a local boot.
15. After rebooting, go through the Start menu and start the image creation process.
16. After creating the vDisk image, log onto the server and start up Ardence Server Administrator.
17. Change the prime client to boot from the vDisk.
18. Boot up all the other clients.
19. At the prompt to add the clients to Ardence, choose the newly created vDisk and add them.

Setting up the Blade PC desktop test bed

We set up the Blade PC desktop test bed by arranging the 10 Wyse Winterm V50 thin clients in a network with a 100Mbps switch. We hosted the HP bc2000 blades in a Blade PC Enclosure. We connected the file server and Blade PC Enclosure to each other through a 1Gbps switch. We then connected the two switches to each other using a 1Gbps uplink port.

Setting up the access infrastructure server in the Blade PC desktop test bed

The Blade PC desktop computing model does not use an access infrastructure server.

Setting up the Blade PC desktop clients

Perform these steps on each blade PC:
1. Install Windows XP Professional.
2. Apply all XP updates (as of July 10, 2007) from the Microsoft Windows Update Web site, including Windows XP SP2.
3. Install Microsoft Office 2003.
4. Apply all Office 2003 updates (as of July 10, 2007) from the Microsoft Office Update Web site.
5. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

15

a.   Open the Control Panel.
    b.   Choose Security Center.
    c.   Click Change the way Security Center Alerts me on the left.
    d.   Uncheck Firewall, Automatic Updates, and Virus Protection.
6. Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
    a.   Open the Control Panel.
    b.   Choose Automatic Updates.
    c.   Select Turn off Automatic Updates.
7. Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
    a.   Open the Control Panel.
    b.   Choose System.
    c.   Choose the System Restore tab.
    d.   Select Turn off System Restore on all drives.
8. Change the IP address to 192.168.1.5[X], where X is the client number of the blade PC. (We numbered the blade PCs 1 through 10 with the last address being 192.168.1.60.)
    a.   Click Start → Control Panel → Select Network Connections.
    b.   Select Local Area Connection.
    c.   In the Local Area Connection Status dialog, select Properties.
    d.   In the Local Area Connection Properties dialog, select Properties.
    e.   Select the Use the following IP address radio button.
    f.   Enter the IP Address.
    g.   Select OK on the top two open dialog boxes.
    h.   Select Close to close the third dialog box.
9. Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
    a.   Right-click My Computer.
    b.   Select Map Network Drive.
    c.   Select Q: from the Drive drop-down menu.
    d.   Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
    e.   Click Finish.
10. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
11. Configure the Visual Test Runtime application so that it will work with all the test scripts:
    a.   Copy the following five Visual Test dll files into \WINDOWS\SYSTEM32:
        •   IEHelper.dll
        •   Vtaa.dll
        •   VTest60.dll
        •   Vtres.dll
        •   WebDrive.dll
    b.   Open a command prompt.
    c.   Type cd \WINDOWS\SYSTEM32, and press Enter.
    d.   For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
        •   IEHelper.dll
        •   Vtaa.dll
        •   WebDrive.dll
12. Change the blade PC to allow remote connections to the desktop.
    a.   Right-click on My Computer and select Properties.
    b.   Click on the Remote tab in the System Properties window.
    c.   Under Remote Desktop, select the option allowing remote desktop connections.
13. Install Adobe Acrobat 8.0 Professional.

Additional Blade PC desktop client setup
1. Boot the file server.
2. Boot the Blade PC Enclosure.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

16

3. Boot the thin client.
4. Change the IP address of the thin client to 192.168.1.6[X], where X is the number of the client.
   a. Click Start → Control Panel → Select Network Connections.
   b. Select Local Area Connection.
   c. In the Local Area Connection Status dialog, select Properties.
   d. In the Local Area Connection Properties dialog, select Properties.
   e. Select the Use the following IP address radio button.
   f. Enter the IP Address.
   g. Select OK on the top two open dialog boxes.
   h. Select Close to close the third dialog box.
5. Configure each thin client to have a display resolution of 1,280 x 1,024 and 24-bit color depth.
6. Create a remote desktop connection with the Blade PC Enclosure.
   a. Click Start → Connection Manager.
   b. In the Connection manager window, click Add.
   c. In the first window, select RDP and click Next.
   d. Under the Network tab, enter the following:
      i. In the Description box: RDP Connection
      ii. In the Server box: 192.168.1.5[X], where X is as above.
   e. Under the Window tab, set the Window Colors to 16 Million and the Window Size to Full screen.
   f. Under the Login tab, enter the following:
      i. In the User Name box: administrator
      ii. For the password: password
7. Double-click the RDP Connection icon to connect to the VM.
8. Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
   a. Right-click My Computer.
   b. Select Map Network Drive.
   c. Select Q: from the Drive drop-down menu.
   d. Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.
   e. Click Finish.
9. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".

Setting up the Well-managed application streaming desktop/vPro test bed

We set up the Well-managed application streaming desktop/vPro test bed by arranging the 10 desktop systems in a network with a 100Mbps switch. We connected the file server and access infrastructure server to each other through a 1Gbps switch. We then connected the two switches to each other using a 1Gbps uplink port.

Setting up the access infrastructure server in the Well-managed application streaming desktop/vPro test bed

1. Install a copy of Microsoft Windows 2003 Server Enterprise Edition, R2.
2. Apply the following updates from the Microsoft Windows Update site:
   - Windows Server 2003 Service Pack 2
   - Windows Server 2003 update (KB927891)
   - Windows Server 2003 Security Update (KB929123)
   - Windows Server 2003 Security Update (KB930178)
   - Windows Server 2003 Security Update (KB931784)
   - Windows Server 2003 Update (KB932168)
   - Windows Server 2003 Security Update (KB932168)
   - Windows Server 2003 Security Update (KB933566)
   - Windows Server 2003 Security Update (KB935839)
   - Windows Server 2003 Security Update (KB935840)
   - Windows Server 2003 Security Update (KB924667-v2)
   - Windows Server 2003 Security Update (KB925902)
3. Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
   a. Open the Control Panel.
   b. Choose Security Center.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

17

     c.   Click Change the way Security Center Alerts me on the left.
     d.   Uncheck Firewall, Automatic Updates, and Virus Protection.
4.   Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
     a.   Open the Control Panel.
     b.   Choose Automatic Updates.
     c.   Select Turn off Automatic Updates.
5.   Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
     a.   Open the Control Panel.
     b.   Choose System.
     c.   Choose the System Restore tab.
     d.   Select Turn off System Restore on all drives.
6.   Install AppStream Server on the server, keeping all defaults.
7.   Create a user for the clients of AppStream.
8.   To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk.
9.   Using Symantec's Ghost utility, make an image of the hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Setting up the Well-managed application streaming desktop/vPro clients
Repeat the steps on each of the 10 clients.
1.   Install Windows XP Professional.
2.   Apply all XP critical updates (as of July 10, 2007) from the Microsoft Windows Update Web site, including
3.   Turn off Windows Service Pack 2 Security Center Pop-up Alerts. Doing so prevents such alerts from occurring during testing and affecting results.
     a.   Open the Control Panel.
     b.   Choose Security Center.
     c.   Click Change the way Security Center Alerts me on the left.
     d.   Uncheck Firewall, Automatic Updates, and Virus Protection.
4.   Turn off Windows Automatic Updates. Doing so prevents such updates from occurring during testing and affecting results.
     a.   Open the Control Panel.
     b.   Choose Automatic Updates.
     c.   Select Turn off Automatic Updates.
5.   Turn off System Restore. Doing so prevents such events from occurring during testing and affecting results.
     a.   Open the Control Panel.
     b.   Choose System.
     c.   Choose the System Restore tab.
     d.   Select Turn off System Restore on all drives.
6.   Change the client's IP address to 192.168.1.5[X], where X is the client number of the PC. (We numbered the PCs 1 through 10 with the last address being 192.168.1.60.)
     a.   Click Start → Control Panel → Select Network Connections.
     b.   Select Local Area Connection.
     c.   In the Local Area Connection Status dialog, select Properties.
     d.   In the Local Area Connection Properties dialog, select Properties.
     e.   Select the Use the following IP address radio button.
     f.   Enter the IP Address.
     g.   Select OK on the top two open dialog boxes.
     h.   Select Close to close the third dialog box.
7.   Map the network drive Q: to \\[servername]\fileserver\user files\user[X], where X is as above.
     a.   Right-click My Computer.
     b.   Select Map Network Drive.
     c.   Select Q: from the Drive drop-down menu.
     d.   Type \\[servername]\fileserver\user files\user[X], where X is as above, as the Folder name.

     e.   Click Finish.
8. Create a desktop shortcut to the Q: network drive. This shortcut's name will be of the form "Shortcut to UserX on [servername]".
9. Configure the Visual Test Runtime application so that it will work with all the test scripts:
    a.   Copy the following five Visual Test dll files into \WINDOWS\SYSTEM32:
- IEHelper.dll
- Vtaa.dll
- VTest60.dll
- Vtres.dll
- WebDrive.dll

    b.   Open a command prompt.
    c.   Type cd \WINDOWS\SYSTEM32, and press Enter.
    d.   For each of the following three dlls, type regsvr32 [dll filename], and press Enter. (This command registers a dll with the system.)
- IEHelper.dll
- Vtaa.dll
- WebDrive.dll

10. To ensure as consistent a starting point as possible for the performance measurements, defragment the hard disk of each PC.
11. Using Symantec's Ghost utility, make an image of each PC's hard disk. (This image let us return to a clean and consistent starting point whenever necessary.)

Additional client setup

This setup process refers to the creation of the application packages for AppStream and the distribution of those packages to the clients.
1. Create a fresh install of Windows XP Professional using all defaults.
2. Install AppStream Package Creator.
3. Using AppStream Package Creator's Snapshot Package option, install Microsoft Office 2003.
4. After Package Creator has finished creating the Office package, copy the package onto the access infrastructure server.
5. Repeat steps 1 and 2.
6. Using AppStream Package Creator's Snapshot Package option, install Adobe Acrobat 8.0.Professional.
7. After Package Creator has finished creating the Acrobat package, copy the package onto the access infrastructure server.
8. Log on to the AppStream interface and select the Well-managed application streaming desktop/vPro server.
9. Load the two packages you created earlier.
10. Go to the AppStream users and give them permission to access the two created packages.

Running the tests

Setting up the servers and clients is much more complicated than the testing process. When you have correctly set up the clients, they will automatically connect to the server(s). Executing the tests on a particular type of client involves three relatively straightforward phases:

1. **Getting the systems ready to go.** In this phase, you make sure all the systems in the test bed are on, appropriately connected (i.e., clients are connected to the file server), and ready for testing.
2. **Setting up the test script you want to run.** Each script has a setup script that you must run once on each client before testing on that client with that script. The setup script makes sure the data files are ready; the application windows are where the test script expects to find them, and so on.
3. **Running the test scripts and recording results.** You must reboot the test bed systems before each run of each test script and start the test script at the same time on all the clients under test.

Phase 1 varies for each test bed. We detail it below in the sections on the test beds. In all of these discussions, we assume you have already completed the setup process we outlined earlier. We also assume any client systems you do not want to include in a test will not be on.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

19

Phase 2 is the same regardless of the type of client you are testing. Once you have readied all the systems to go and are working on a client, follow this process to prepare the client to run a test script:

1. Double-click the desktop shortcut Shortcut to UserX at [servername], where X is the number of the client and servername is the name you gave the file server.
2. You will see four folders, one for each script. Open the folder that contains the script you are testing.
3. Inside that folder you will find a folder named SC1. Double-click that folder.
4. You will see three folders: Content, Results, and Scripts. The Scripts folder contains the individual script files. Double-click the Scripts folder.
5. In the Scripts folder, find the files SC1-Setup.pc6 and SC1main.pc6. Create desktop shortcuts to each of them.
6. Some scripts require an additional preparation or cleanup program. If so, the Script folder will contain a third file named SC1-Prep.pc6 or SC1cleanup.pc6, respectively. If either file exists, create a desktop shortcut to it.
7. Run SC1-Setup.

Phase 3 is largely the same regardless of the type of client. Once you have finished the above script setup phase, do the following for each test you want to run:

1. Reboot all the servers and the clients you will be using in the test. This process varies by client type; we outline it for each client test bed below.
2. Wait 10 seconds after the Windows hourglass has disappeared on all the clients to ensure a consistent starting state.
3. On each client you want to test, if there is a shortcut to SC1-Prep or SC1cleanup, do the following:
   a. Double-click that shortcut.
   b. Wait until you see a confirmation window indicating that prep has completed, or, in the case of SC1cleanup, wait 30 seconds.
4. Start the script at the same time on all the clients you are testing by clicking the Shortcut to SC1main and pressing Enter on each client.
5. When the test completes, record the results of each client.

As we discussed at the beginning of the Test methodology section, we ran each script five times on each test configuration of each network (e.g., five times with one active PC, five times with two active PCs, and so on.)

In the following three subsections, we detail the first phase for each of the three types of test beds.

Testing the Terminal/Presentation server computing model
This section provides the test execution preparation steps specific to the Terminal/Presentation server test bed.

Getting the Terminal/Presentation server network systems ready to go
Follow these steps to ready the file server, Citrix server, and the Terminal/Presentation server clients:

1. Power on the file server.
2. Power on the Citrix server.
3. When the servers are fully active, power on the Wyse systems you are testing.

Rebooting the Terminal/Presentation server test systems
Follow these steps to ready the file server, the Citrix server, and the Terminal/Presentation server clients for testing:

1. Click Start → Restart on one Terminal/Presentation server client to reset the Citrix server.
2. Once all the Wyse systems are disconnected from the Citrix server, shut down the Wyse Clients.
   a. Click Start → Log Off.
   b. Choose the Shut Down the System option.
   c. Press Enter.
3. Log onto the file server as administrator.
4. Click Start → Shut Down.
5. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
6. Type an explanatory comment in the comment box.
7. Press Enter.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

20

8. Once the servers are fully active, power on the Wyse systems you are testing.

Testing the Typically managed rich desktop clients
This section provides the test execution preparation steps specific to the Typically managed rich desktop test bed.

Getting the Typically managed rich desktop test bed systems ready to go
Follow these steps to ready the file server and PCs for testing:
1. Power on the file server.
2. When the server is fully active, power on the PCs you are testing.

Rebooting the Typically managed rich desktop test bed systems
Follow these steps to reboot the file server and PCs for testing:
1. Click Start→Shut Down on each active PC.
2. Select Shut Down from the menu on each active PC.
3. Log on to the file server as administrator.
4. Click Start → Shut Down.
5. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
6. Type an explanatory comment in the comment box.
7. Press Enter.
8. You may see a warning window that says shutting down will close the remote connections and asks if you want to end them. Click Yes, and the file server will restart.
9. When the server is fully active, power on the PCs you are testing.

Testing the Well-managed OS streaming desktop/vPro computing model
This section provides the test execution preparation steps specific to the Well-managed OS streaming desktop/vPro PCs.

Getting the Well-managed OS streaming desktop/vPro test bed systems ready to go
Follow these steps to ready the file server, Ardence server, and the Ardence PCs for testing:
1. Power on the file server.
2. Power on the Ardence server.
3. When the servers are fully active, power on the PCs you are testing.

Rebooting the Well-managed OS streaming desktop/vPro test bed systems
Follow these steps to ready the file server, Ardence server, and Ardence PCs you are testing:
1. Click Start→Shut Down on each active PC.
2. Select Shut Down from the menu on each active PC.
3. Log on to the file server as administrator.
4. Click Start → Shut Down.
5. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
6. Type an explanatory comment in the comment box.
7. Press Enter.
8. You may see a warning window that says shutting down will close the remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
9. Log onto the Ardence server as administrator.
10. Click Start→ Shut Down.
11. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
12. Press Enter.
13. You may see a warning window that says shutting down will close the remote connections and that asks if you want to end them. Click Yes, and the server will restart.
14. When the servers are fully active, power on the PCs you are testing.

Testing the Blade PC desktop computing model
This section provides the test execution preparation steps specific to the Blade PC desktop test bed.

Getting the Blade PC desktop test bed systems ready to go
Follow these steps to ready the files server, CCI server, and CCI clients for testing:
1. Power on the file server.
2. Power on the CCI blades that you will be testing.
3. When the servers are fully active, power on the Wyse systems you are testing.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

21

Rebooting the Blade PC desktop test systems
Follow these steps to ready the file server, the Citrix server, and the Terminal/Presentation server clients for testing:
1. Double-click on the Restart batch file on the desktop of the Wyse systems to reset the CCI blades.
2. Click Start → Log Off and choose Shut Down the System.
3. Log onto the file server as administrator.
4. Click Start → Shut Down.
5. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
6. Type an explanatory comment in the comment box.
7. Press Enter.
8. You may see a warning window that says shutting down will close the remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
9. When the servers are fully active, power on the Wyse systems you are testing.

Testing the Well-managed application streaming desktop/vPro computing model
This section provides the test execution preparation steps specific to the Well-managed application streaming desktop/vPro test bed.

Getting the Well-managed application streaming desktop/vPro test bed systems ready to go
Follow these steps to ready all servers and clients for testing:
1. Power on the file server.
2. Power on the AppStream server.
3. When the servers are fully active, power on the PCs you are testing.

Rebooting the Well-managed application streaming desktop/vPro test bed systems
Follow these steps to ready the servers and PCs for testing:
1. Click Start→Shut Down on each active PC.
2. Select Shut Down from the menu on each active PC.
3. Log on to the file server as administrator.
4. Click Start → Shut Down.
5. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
6. Type an explanatory comment in the comment box.
7. Press Enter.
8. You may see a warning window that says shutting down will close the remote connections and that asks if you want to end them. Click Yes, and the file server will restart.
9. Log onto the AppStream server as administrator.
10. Click Start→ Shut Down.
11. Make sure that in the list box under What do you want the computer to do?, you have selected Restart.
12. Press Enter.
13. You may see a warning window that says shutting down will close the remote connections and that asks if you want to end them. Click Yes, and the server will restart.
14. When the servers are fully active, power on the PCs you are testing.

Application scenarios: Descriptions and instructions for running manually
This section summarizes the script for each application scenario and explains how we manually tested and timed each of those scenarios. Though the vast majority of our discussions in this report focus on the results of the automated tests, we verified that manually performing the same functions yielded results similar to those of the automated scripts.

As the instructions below reflect, to get the most consistent possible timings and to make our hand-timed actions more like the ones the automated scripts perform, we sometimes followed procedures for launching applications that were different from those typical users would follow. In these cases, we also independently verified that the typical user procedures would still show similar results.

Consequently, we are confident that our measurements are accurate and are not artifacts of the measurement or scripting technology.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

22

We ran all application scenarios five times on each of the systems under test, and we reported the median of those runs.

The following subsections, which assume you have already completed all of the setup work in the Test methodology section, describe how to run each of the individual scenarios by hand.

Single-task scenario: Calculating subtotals in Microsoft Excel

The application involved
- Microsoft Office Excel 2003

The data file involved
- Sales2002a1.xls, a 1.79MB Excel worksheet (located on the file server)

The script
The script for the scenario performs the following tasks:
- Open Sales2002a1.xls. (We did not time that task because we focused on a single function.)
- Start the Excel timer, and perform the subtotal function.
- Stop the Excel timer when Excel finishes calculating the subtotals.
- Close Excel. (We did not time that task because we focused on a single function.)

The manual process
To execute the test, follow these instructions. You will need one stopwatch.
1. Reboot the system.
2. Open Sales2002a1.xls.
3. Select Data | Subtotals...
4. Fill in the Subtotal dialog as follows:
   - At each change in: Size.
   - Use function: Average.
   - Add subtotal to: Quantity.
   - Uncheck Replace current subtotals.
5. Start stopwatch, and press OK.
6. Stop stopwatch when the Inserting Subtotals progress bar goes away and the status bar says Ready.
7. Close Excel, choosing No when Excel asks whether you want to save.

Single-task scenario: Compressing a PDF from within Adobe Acrobat

The application involved
- Adobe Acrobat 8.0 Professional

The data file involved
- Computing.pdf, a 4.01MB PDF file (on the file server)

The script
The script for the scenario performs the following tasks:
- Open Computing.pdf. (We did not time that task because we focused on a single function.)
- Start the Acrobat timer, and tell Acrobat to compress the PDF.
- Stop the Acrobat timer when the Conversion Warning dialog displays.
- Close the Conversion Warning window.
- Close Acrobat.
- Delete Compress.pdf, the file the script just created. (We did not time these three final tasks because we focused on a single function.)

The manual process
To execute the test, follow these instructions. You will need one stopwatch.
1. Reboot the system.
2. Open Computing.pdf.
3. Select File | Reduce File Size.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

23

4. In Reduce File Size dialog, select Acrobat 7.0 or later.
5. Press OK.
6. In the Save As dialog, give the new file the name Compress.
7. Start the Acrobat stopwatch, and press Save.
8. Stop the Acrobat stopwatch when a Conversion Warning dialog displays.
9. Press Enter to close the Conversion Warning dialog.
10. Exit Acrobat.
11. Delete Compress.pdf.
12. Empty the Recycle Bin.

Multitasking scenario: Changing the view in a Microsoft PowerPoint presentation while compressing a folder in Windows Explorer

The applications involved
- Microsoft Windows Explorer for Windows XP Professional (Service Pack 2)
- Microsoft Office PowerPoint 2003

The data files involved
- FourFiles, a 265MB folder that the scenario uses to create a 168MB compressed (zipped) folder (on the file server for the thin clients; local for the rich clients)
- Content.ppt, a 30.4MB Microsoft PowerPoint presentation (on the file server)

The script
The script for the scenario performs the following tasks:
- Open Windows Explorer. (We did not time this task, because it occurs outside the multitasking section of the script.)
- Navigate to FourFiles.
- Start the timer for Explorer Compress, and start compressing FourFiles.
- Start the PowerPoint Open timer, and double-click the Content.ppt desktop shortcut.
- Stop the PowerPoint Open timer when the bottom slide in the slide viewer loads.
- Start the PowerPoint Change View timer, and select View | Slide Sorter.
- Stop the PowerPoint Change View timer when the last slide loads in the Slide Sorter view.
- Stop the Explorer Compress timer when Explorer finishes compressing the file.
- Close all open applications. (We did not time these tasks, because they occur outside the multitasking section of the script.)

The manual process
First, prepare each system by following these steps once:
1. Open Windows Explorer.
2. Ensure that it allows enough space on the right to allow double-clicking a desktop shortcut there.
3. Create a desktop shortcut to Content.ppt. Place it on the right side of the desktop, to the right of the Explorer window.

To execute the test, follow these instructions. You will need three stopwatches to time three different tasks.
1. Reboot the system.
2. Open Windows Explorer.
3. Navigate to the folder that contains FourFiles.
4. Start the first stopwatch, and click Send to | Compressed (zipped) folder.
5. Start the second stopwatch, and double-click the Content.ppt desktop shortcut.
6. Stop the second stopwatch when the slide viewer finishes displaying the slides that fit in the PowerPoint window.
7. Start the third stopwatch, and select View | Slide Sorter from the PowerPoint menu.
8. Stop the third stopwatch when the slider sorter finishes displaying the slides that fit in the PowerPoint window.
9. Stop the first stopwatch when Explorer finishes creating the compressed FourFiles.zip.
10. Close all open applications, choosing No if any application asks whether to save changes.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

24

11. Delete FourFiles.zip.
12. Empty the Recycle Bin.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

25

Appendix A – Overview of test bed configurations

In this appendix, we present the test beds for each of the compute models we tested. Appendix B contains more detailed configuration information.

Terminal/Presentation server test bed

Figure 8 illustrates the Terminal/Presentation server test bed, which includes the following components:

- Thin clients (Wyse Winterm V50)
    - Processor: 1GHz Via C3
    - Memory: 128MB flash/256 MB DDR RAM
    - Operating system: Wyse Linux V6

- Access infrastructure server (hand built)
    - Processors: Two 3GHz Intel Xeon 5160 dual-core processors
    - Memory: 16GB DDR2 SRAM
    - Motherboard: Supermicro X7DBE+
    - Disks: Four 73GB Seagate Cheetah ST373455SS disks
    - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2
    - Thin client management software: Citrix Presentation Server 4.5

- File Server (hand built)
    - Processors: One 3.4GHz Intel Xeon processor
    - Memory: 2GB DDR2 SRAM
    - Motherboard: HP 382146-405
    - Disks: One Western Digital WD740ADFD-00NLR1 disk
    - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2
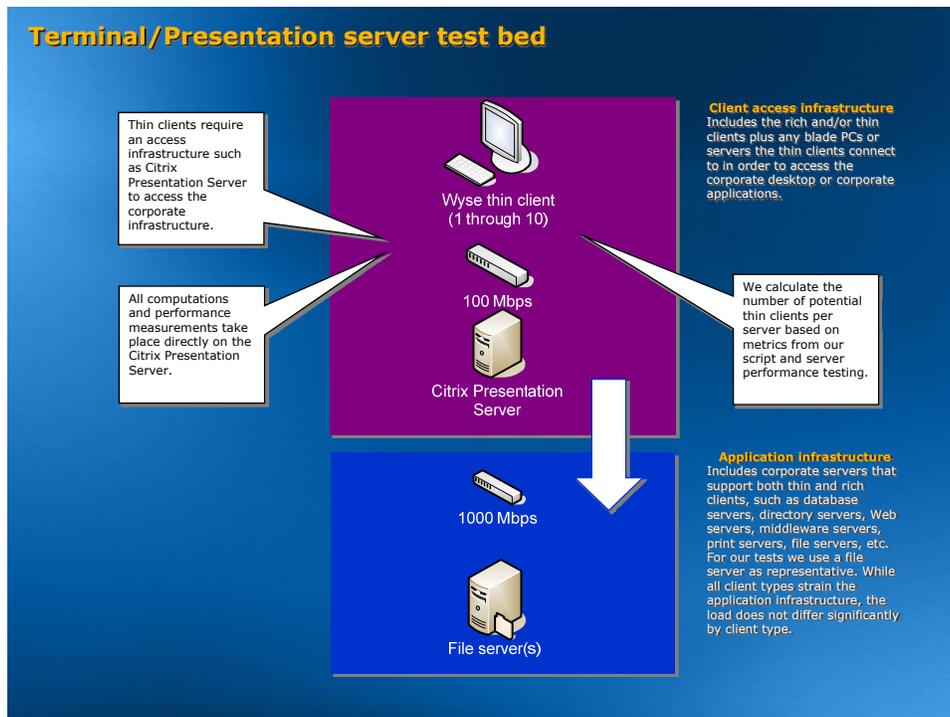

Figure 8: Terminal/Presentation server test bed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

26

Typically managed rich desktop test bed

Figure 9 illustrates the Typically managed rich desktop test bed, which includes the following components:

- Rich Clients (hand built)
  - Processor: 2.13 GHz Intel Core 2 Duo E6400
  - Memory: 1GB DDR2 SRAM
  - Motherboard: Intel DQ965GF
  - Disk: 160 GB WD Caviar WD1600JS
  - Operating System: Windows XP Professional, version 2002 with Service Pack 2

- File Server (hand built)
  - Processors: One 3.4GHz Intel Xeon processor
  - Memory: 2GB DDR2 SRAM
  - Motherboard: HP 382146-405
  - Disks: One Western Digital WD740ADFD-00NLR1
  - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2
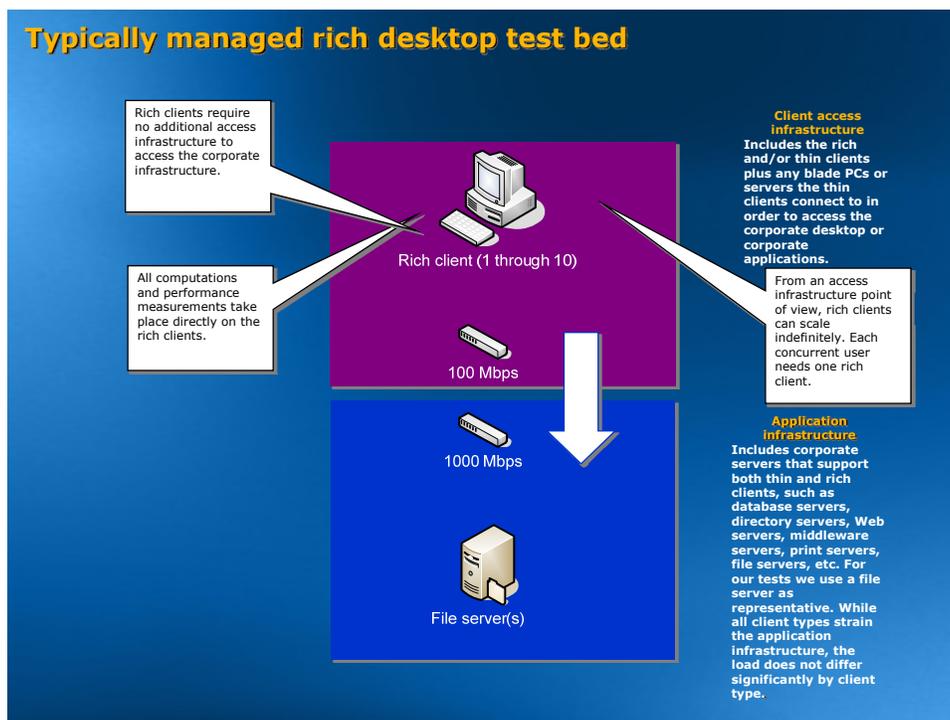

Figure 9: Typically managed rich desktop test bed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

27

Well-managed OS streaming desktop/vPro test bed

Figure 10 illustrates the Well-managed OS streaming desktop/vPro test bed, which includes the following components:

- Rich Clients (hand built)
    - Processor: 2.13 GHz Intel Core 2 Duo E6400
    - Memory: 1GB DDR2 SRAM
    - Motherboard: Intel DQ965GF
    - Disk: 160 GB WD Caviar WD1600JS
    - Operating System: Windows XP Professional, version 2002 with Service Pack 2
    - Streaming software: Ardence Evaluation Client 4.1

- Access infrastructure server (hand built)
    - Processors: Two 3GHz Intel Xeon 5160 dual-core processors
    - Memory: 16GB DDR2 SRAM
    - Motherboard: Supermicro X7DBE+
    - Disks: Four 73GB Seagate Cheetah ST373455SS disks
    - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2
    - Streaming software: Ardence Evaluation Server 4.1 OS

- File Server (hand built)
    - Processors: One 3.4GHz Intel Xeon processor
    - Memory: 2GB DDR2 SRAM
    - Motherboard: HP 382146-405
    - Disks: One Western Digital WD740ADFD-00NLR1
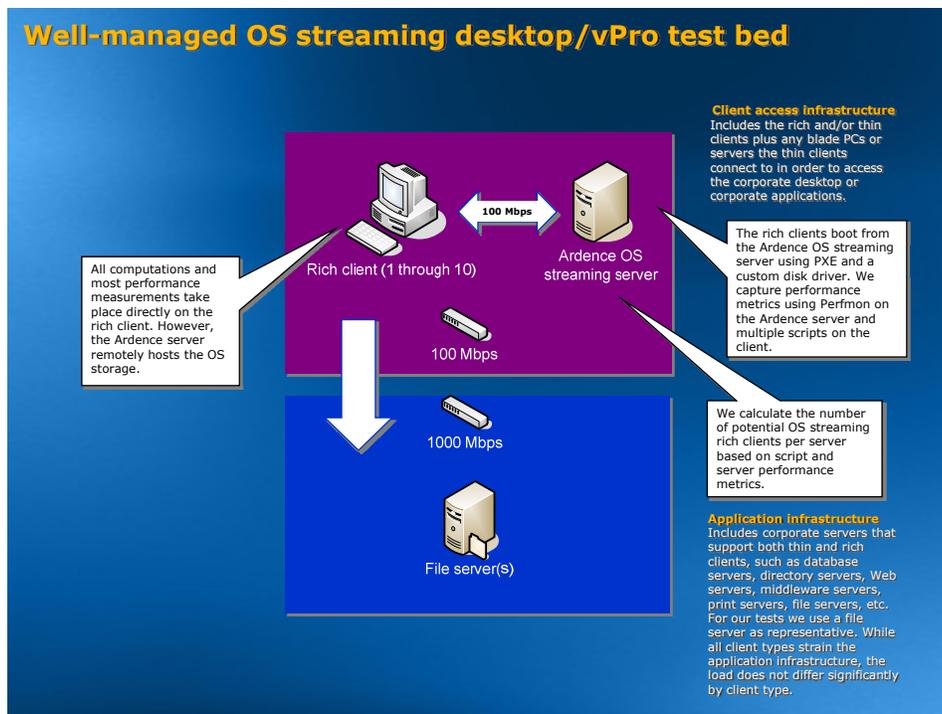   - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2

Figure 10: Well-managed OS streaming desktop/vPro test bed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

28

Blade PC desktop test bed

Figure 11 illustrates the Blade PC desktop test bed, which includes the following components:

- Blade PCs: HP BladeSystem bc2000 Blade PC
  - Processor: AMD Athlon 64 2100+ 1.20GHz
  - Memory: 1GB DDR2 RAM
  - Disk: 80 GB Samsung HM080HI
  - Operating system: Windows XP Professional, version 2002 with Service Pack 2

- Thin Clients (Wyse Winterm V50)
  - Processor: 1GHz Via C3 Memory: 128MB flash/256 MB DDR RAM
  - Operating system: Wyse Linux V6

- File Server (hand built
  - Processors: One 3.4GHz Intel Xeon processor
  - Memory: 2GB DDR2 SRAM
  - Motherboard: HP 382146-405
  - Disks: One Western Digital WD740ADFD-00NLR1
  - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2

  Note: We assigned each thin client a blade PC via a static IP address. No session manager was running.
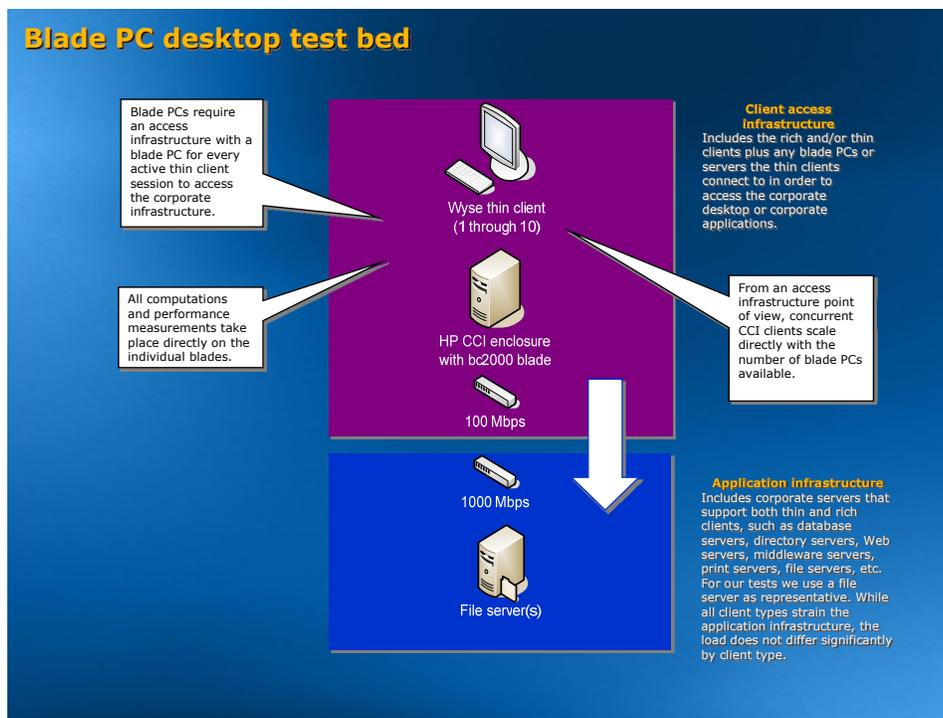

Figure 11: Blade PC desktop test bed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

29

Well-managed application streaming desktop/vPro test bed

Figure 12 illustrates the Well-managed application streaming desktop/vPro test bed, which includes the following components:

- Rich Clients (hand built)
    - Processor: 2.13 GHz Intel Core 2 Duo E6400
    - Memory: 1GB DDR2 SRAM
    - Motherboard: Intel DQ965GF
    - Disk: 160 GB WD Caviar WD1600JS
    - Operating System: Windows XP Professional, version 2002 with Service Pack 2
    - Application streaming software: AppStream Technology Windows Edition 5.2.1 - Client

- AppStream Server (hand built)
    - Processors: Two 3GHz Intel Xeon 5160 dual-core processors
    - Memory: 16GB DDR2 SRAM
    - Motherboard: Supermicro X7DBE+
    - Disks: Four 73GB Seagate Cheetah ST373455SS disks
    - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2
    - Application streaming software: AppStream Technology Windows Edition 5.2.1 – Server

- File Server (hand built)
    - Processors: One 3.4GHz Intel Xeon processor
    - Memory: 2GB DDR2 SRAM
    - Motherboard: HP 382146-405
    - Disks: One Western Digital WD740ADFD-00NLR1
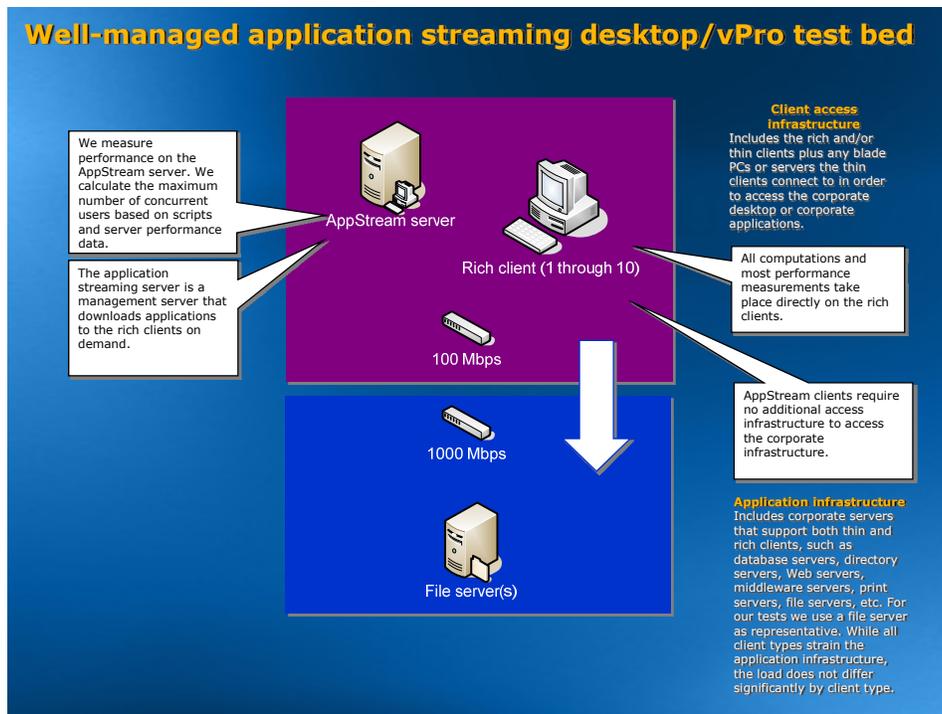   - Operating system: Windows Server 2003 R2 Enterprise with Service Pack 2

Figure 12: Well-managed application streaming desktop/vPro test bed.

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

30

Appendix B – Detailed test bed configurations

Servers

Servers	Supermicro X7DB8 (access infrastructure server)	HP ProLiant DL360 (file server)
General		
Processor and OS kernel: (physical, core, logical)/(UP, MP)	2P, 4C, 4L/MP	1P, 1C, 2L/MP
Number of physical processors	2	1
Single/dual-core processors	Dual	Single
System Power Management Policy	Always on	Always on
CPU		
Vendor	Intel	Intel
Name	Intel Xeon 5160	Intel Xeon
Stepping	4	A
Socket type	771 LGA	604 mPGA
Core frequency (GHz)	3.0	3.4
Front-side bus frequency (MHz)	1,333	800
L1 cache	32 KB + 32 KB (per core)	16 KB + 12 Kμops
L2 cache	4,096 KB (shared)	2,048 KB
Platform		
Vendor and model number	Supermicro	HP
Motherboard model number	Supermicro X7DB8	382146-405
Motherboard chipset	Intel 5000P	Intel E7520
Motherboard revision number	92	A05
Motherboard serial number	TM66S06522	USE617N2DF
BIOS name and version	Phoenix Technologies LTD 6.00	HP P54
BIOS settings	Default	Default
Memory module(s)		
Vendor and model number	Kingston KVR667D2D8F5/1G	Infineon HYS72T28000HR-5-A
Type	PC2-5300 FB-DDR2	PC2-3200 DDR2
Speed (MHz)	667	400
Speed in the system currently running @ (MHz)	333	200
Timing/latency (tCL-tRCD-tRP- tRASmin)	5-5-5-15	3-3-3-11
Size	16,382 MB	2,048 MB
Number of RAM modules	16 x 1,024 MB	2 x 1,024 MB
Chip organization	Double-sided	Double-sided
Channel	Dual	Single
Hard disk		
Vendor and model number	Seagate ST373455SS	Western Digital WD740ADFD- 00NLR1
Number of disks in system	4	1
Size	73 GB	74 GB
Buffer size	16 MB	16 MB
RPM	15,000	10,000
Type	SAS	SATA
Controller	Intel RAID Controller SRSCSAS144E	Intel 6300ESB (ICH-S)
Controller driver	Intel Logic Corp 1.23.0.32	Microsoft 5.2.3790.0

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models -
Supporting data for performance and sizing calculations

31

Servers	Supermicro X7DB8 (access infrastructure server)	HP ProLiant DL360 (file server)
Operating system (Windows)		
Name	Microsoft Windows Server 2003 R2 Enterprise	Microsoft Windows Server 2003 R2 Enterprise
Build number	3790	3790
Service Pack	SP2	SP2
Microsoft Windows update date	07/03/2007	07/03/2007
File system	NTFS	NTFS
Kernel	ACPI Multiprocessor PC	ACPI Multiprocessor PC
Language	English	English
Microsoft DirectX version	9.0c	9.0c
Graphics		
Vendor and model number	ATI ES1000	ATI RAGE XL
Chipset	ES1000	ATI RAGE XL
BIOS version	01.00	GR-xlcpq-5.88-4.333
Type	Integrated	Integrated
Memory size	16 MB	8 MB shared
Resolution	1,280 x 1,024	1,280 x 1,024
Driver	Microsoft 5.2.3790.0	ATI 5.10.2600.6014
Network card/subsystem		
Vendor and model number	Intel PRO/1000 EB Network Connection	HP NC7782 Gigabit Server Adapter
Type	Integrated	Integrated
Driver	Intel 9.7.34.0	HP 10.39.0.0
Additional card information	-	HP NC7782 Gigabit Server Adapter #2
Additional card type	-	Integrated
Additional card driver	-	HP 10.39.0.0
Optical drive		
Vendor and model number	MATSHITA SR-8178	HLDS GCR-8240N
Type	DVD-ROM	CD-ROM
Interface	SATA	SATA
Dual/single layer	Dual	Single
USB ports		
Number of ports	4	2
Type of ports (USB1.1, USB2.0)	3 USB 1.0, 1 USB 2.0	2.0
RAID		
Type	RAID 0	N/A
Size	274 GB	N/A
Driver version	Intel Logic Corp 1.23.0.32	N/A

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

32

Servers	Supermicro X7DB8 (access infrastructure server)	HP ProLiant DL360 (file server)
RAID devices		
Vendor and model number	Intel RAID Controller SRSCSAS144E	N/A
Firmware version	1.03.00-0211	N/A
BIOS version	1.03-08_02	N/A
Host interface	PCI-Express	N/A

Clients

Clients	Hand-built standard rich client	HP BladeSystem bc2000 Blade PC	Wyse Winterm V50 thin client
General			
Processor and OS kernel: (physical, core, logical)/(UP, MP)	1P, 2C, 2L/MP	1P, 1C, 1L/UP	1P, 1C, 1L/UP
Number of physical processors	1	1	1
Single/dual-core processors	Dual	Single	Single
System Power Management Policy	Home/Office desk	Home/Office desk	N/A
CPU			
Vendor	Intel	AMD	Via
Name	Core 2 Duo	Athlon 64	C3
Model number	E6400	2100+	-
Stepping	6	2	-
Socket type	775 LGA	S1 (638)	370
Core frequency (GHz)	2.13	1.2	1.0
Front-side bus frequency (MHz)	1,066	800	-
L1 cache	32 KB + 32 KB (per core)	64 KB + 64 KB	-
L2 cache	2,048 KB	512 KB	64 KB
Platform			
Vendor and model number	Built in house	HP Blade PC bc2000	Wyse Winterm V50
Motherboard model number	Intel DQ965GF	HP 0A84h	-
Motherboard chipset	Intel Q963	ATI RS690/RS690M	-
Motherboard revision number	C1	00	-
Motherboard serial number	BQGF64200DXU	MXL72316NB	-
BIOS name and version	Intel CO96510J.86A.4462. 2006.0804.2059	HP 786E5 v01.06	1.11
BIOS settings	Setup default	Setup default	Setup default

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

33

Clients	Hand-built standard rich client	HP BladeSystem bc2000 Blade PC	Wyse Winterm V50 thin client
Memory module(s)			
Vendor and model number	Kingston KHX6400D2K2/1G	Hyundai Electronics HYMP564S64CP6-Y5	DSL CL2.5
Type	PC2-5300 DDR2	PC2-5300 DDR2	PC 2700 DDR
Speed (MHz)	667	667	667
Speed running in the system (MHz)	333	333	333
Timing/Latency (tCL-tRCD-tRP-tRASmin)	5-5-5-15	5-5-5-15	-
Size	1,024 MB	1,024 MB	256 MB
Number of memory modules	2 x 512 MB	2 x 512 MB	1
Chip organization	Single-Sided	Double-sided	Double-sided
Channel	Dual	Dual	Single
Hard disk or flash memory			
Vendor and model number	WD Caviar WD1600JS-22MHB1	Samsung HM080HI	Samsung Flash Memory P770478-10LQ
Size	160 GB	80 GB	128 MB
Buffer size	8 MB	8 MB	N/A
RPM	7,200	7,200	N/A
Type	SATA	SATA	N/A
Controller	Intel 82801H0 (ICH8D0)	ATI TechIXP SB600	N/A
Controller driver	Microsoft 5.1.2535.0	Microsoft 5.1.2535.0	N/A
Operating system			
Name	Microsoft Windows XP Professional	Microsoft Windows XP Professional	Wyse Linux V6
Build number	5.01.2600	5.01.2600	6.3.1
Service pack	SP2	SP2	-
File system	NTFS	NTFS	-
Kernel	ACPI Multiprocessor PC	ACPI Uniprocessor PC	2.6x
Language	English	English	English
Microsoft DirectX version	9.0c	9.0c	-
Graphics			
Vendor and model number	Intel GMA 3000	ATI	-
Type	Integrated	Integrated	Integrated
Chipset	Intel GMA 3000	-	-
BIOS version	1348	-	-
Memory size	128 MB	-	-
Resolution	1,280 x 1,024	1,280 x 1,024	1,280 x 1,024
Driver	Intel 6.14.10.4618	-	-
Sound card/subsystem			
Vendor and model number	Sigma Tel High Definition Audio CODEC	N/A	Integrated
Driver	Sigma Tel 5.10.5067.0	-	-

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

34

Clients	Hand-built standard rich client	HP BladeSystem bc2000 Blade PC	Wyse Winterm V50 thin client
Ethernet			
Vendor and model number	Intel 82566DM Gigabit Network Connection	Broadcom NetLink Fast Ethernet	10/100 Base-T Fast Ethernet twisted pair (RJ-45)
Driver	Intel 9.4.17.0	Broadcom 10.24.0.0	-
Optical drive(s)			
Vendor and model number	TSSTcorp SH-S183L	N/A	N/A
Type	DVD/CD-ROM (RW)	N/A	N/A
Interface	SATA	N/A	N/A
Dual/single layer	Dual layer	N/A	N/A
USB ports			
Number	10	2 (only with adapter)	3
Type	2.0	2.0	2.0
IEEE 1394			
Number	1	0	0
Monitor			
Type	ViewSonic Optiquest Q7	ViewSonic Optiquest Q7	ViewSonic Optiquest Q7
Screen size	17"	17"	17"
Refresh rate (Hz)	60	1	60

Principled Technologies, Inc.: Total cost of ownership analysis for various computing models - Supporting data for performance and sizing calculations

35